

**SECTION 16152****VARIABLE FREQUENCY DRIVES****PART 1 - GENERAL****1.01 SCOPE**

- A. This section covers minimum specifications for a Variable Frequency Drive (VFD) system when required for control in a pumping station facility.
- B. The Contractor shall furnish the VFD system in a cabinet so that only external field installed wires are required for a fully operational system.
- C. This specification lists the minimum VFD performance requirements for this project. Each supplier shall list any exceptions to the specification. If no departures from the specification are identified, the supplier shall be bound by the specification.

**1.02 UNIT RESPONSIBILITY**

All drives at new installations shall be provided by one manufacturer who shall assume unit responsibility for proper operation of the system and every component within it.

**1.03 QUALITY ASSURANCE**

- A. The Contractor shall submit documentation verifying that the drive manufacturer has at least ten (10) years of experience in manufacturing and integrating VFD systems of similar size, type and scope.
- B. All equipment, materials and components used in the system shall be new, the standard current products of manufacturers regularly engaged in the production of such equipment, the manufacturer's latest design and UL labels when applicable.
- C. The Variable Frequency Drive shall be built to meet the latest standards of ANSI, IEEE, NEMA and the National Electric Code.
- D. The manufacturer shall be both ISO-901 and ISO- 14001 certified.
- E. All products shall be CE marked, UL labeled, and meet the requirements of UL-508C.
- F. To ensure quality and minimize infantile failures on the jobsite, all VFD's shall be completely tested by the manufacturer. The VFD shall operate a dynamometer at full load and speed under elevated temperature conditions.
- G. All optional features shall be functionally tested at the factory for proper operation.
- H. Factory test documentation shall be available upon request.

#### 1.04 SUBMITTALS

- A. Submit for review six copies of properly identified manufacturer's literature and shop drawings of VFD and major components. Submittal shall include manufacturer's performance data including dimensional drawings, power circuit diagrams, installation and maintenance manuals, warranty description, VFD's FLA rating, certification agency file numbers, catalog information and catalog cut-sheets for all major components.
- B. Approval for fabrication and installation will be made only after submittal and review of all shop drawings and manufacturer's literature. The information required for approval shall include as a minimum, the following:
  - 1. Computer generated 3-line electrical diagram of power and control.
  - 2. Submit a computer generated Harmonic Distortion Analysis for the jobsite location.
  - 3. Description of control operation, system operation and analog signal processing.
  - 4. System block, schematic and interconnection diagrams.
  - 5. Detailed drawing of the enclosure (size, construction, mounting, etc.)
  - 6. Stamped and sealed report and calculation by a Florida Registered Engineer that all anchorages, shielding plates, skeleton frames and foundation slab for the enclosure comply with the wind loads of the "Florida Building Code" and the "Designed Loads for Buildings and Other Structures" (ASCE 7-93 Section 6). All wind pressures, including calculated uplift shall be modified by the corresponding use and shape factors, including those required for the Coastal Building Zone, if applicable.

#### 1.05 DESIGN DATA

- A. The system shall be capable of operating pumps in a variable speed mode keeping sewage level, despite system demands, within a settable range and without causing a sewage overflow.
- B. Each pump shall be started via reduced-voltage or soft-start and operate in variable speed mode. Upon VFD failure, pump(s) shall be capable of starting via reduce-voltage or soft-start and operate in bypass mode. Transition from variable speed mode to by-pass mode shall require an operator.
- C. The available power shall be 230 or 460 VAC, 3 phase, 60 Hz.

- D. The Operation Control Scheme for the pumping station, as regard VFD's, shall be as follows:
1. The (automatically or manually selected) lead pump shall start when the wet well level reaches the point that calls the lead pump to come on. Pumps shall always start at a minimum speed and accelerate to the speed require to maintain the level within a settable proportional band.
  2. The lag pump shall not be started until:
    - a) The lead pump is running at full speed.
    - b) The level has increased to the point when two pumps are required to handle the flow.
  3. With two pumps operating simultaneously, both shall run at same speed.
  4. On decreasing level and more than one pump in operation, all the "Lag" pumps shall turn off sequentially in reverse order (last "On" shall be first "Off"). However, no pump shall operate below 60% of SRPM for a period of time exceeding 300 seconds.
  5. Pumps shall not run below 60% of SRPM. When a pump is running at this speed on decreasing level, the pump shall keep that speed until the level reaches a preselected low level point when the pump shall be turned off.
  6. To prevent excessive cycling of the pumps, adjustable time delays shall precede the restating of the pumps after a shut down.
  7. Pump speed and wet well levels that indicate control actions shall be adjustable.

## **PART 2 - PRODUCTS**

### 2.01 ACCEPTABLE MANUFACTURERS

- A. Danfoss VLT<sup>7</sup> 8000 AQUA Series VFD (Variable Frequency Drive)
- B. "Square D" VFD (Variable Frequency Drive)
- C. Or approved equal.

### 2.02 GENERAL

- A. Furnish complete VFD as specified herein or in the equipment schedule for loads designated to be variable speed. VFD's shall be both constant and variable torque rated.
- B. The VFD shall convert incoming fixed frequency three-phase AC power into a variable frequency and voltage for controlling the speed of three-phase AC induction motors. The VFD shall be a six-pulse input design, and the input voltage

rectifier shall employ a full wave diode bridge; VFD's utilizing controlled Silicone Control Rectifiers (SCR) rectifiers shall not be acceptable. The output waveform shall closely approximate a sine wave. The VFD shall be a Pulse Width Modulated (PWM) output design utilizing current Industrial Grade Bipolar Transistor (IGBT) inverter technology and voltage vector control of the output PWM waveform.

- C. The VFD shall include a full-wave diode bridge rectifier and maintain a displacement power factor of near unity regardless of speed and load.
- D. The manufacturer of the VFD shall demonstrate a continuous period of manufacturing and development of VFD's for a minimum of 10 years. VFD's that are brand-labeled are not acceptable.
- E. The VFD shall produce an output waveform capable of handling maximum motor cable distances of up to 1,000 ft. (unshielded) without tripping.
- F. The VFD shall utilize VVC<sup>PLUS</sup>, an output voltage-vector switching algorithm, or equivalent, in both variable and constant torque models. VVC<sup>PLUS</sup> provides rated RMS fundamental voltage from the VFD. This allows the motor to operate at a lower temperature rise, extending its thermal life. The VFD's that cannot produce rated RMS fundamental output voltage or require the input voltage to be increased above motor nameplate value to achieve rated RMS fundamental output voltage are not acceptable.
- G. The VFD selected must be able to source the motor's full load nameplate amperage (fundamental RMS) on a continuous basis, and be capable of running the motor at it's nameplate RPM, voltage, current, and slip without having to utilize the service factor of the motor.
- H. The VFD will be capable of running either variable torque (VT) or constant torque (CT) loads. In variable torque applications, the VFD shall provide a CT-start feature and be able to provide full torque at any speed up to the base speed of the motor. In either CT or VT mode, the VFD shall be able to provide its full rated output current continuously and 110% of rated current for 60 seconds.
- I. An Automatic Energy Optimization (AEO) selection feature shall be provided in the VFD to minimize energy consumption in variable torque applications. This feature shall dynamically adjust output voltage in response to load, independent of speed. This feature shall incorporate power factor compensation. Output voltage adjustment based upon frequency alone is not acceptable for single motor VT configurations.
- J. An initial ramp function shall be available to provide a different beginning ramp time, up to 360 seconds, for application requiring a faster or slower ramp than normal operation.
- K. Switching of the input power to the VFD shall be possible without interlocks of damage to the VFD at a minimum interval of 2 minutes.
- L. Switching of power on the output side between the VFD and the motor shall be

possible with no limitation or damage to the VFD and shall require no additional interlocks.

- M. The VFD shall have temperature controlled cooling by an air conditioning system to minimize internal losses.
- N. VFD shall provide full torque to the motor given input voltage fluctuations of up to  $\pm 10\%$  of the rated input voltage. Additionally, sustained line voltage reductions up to 15% shall not cause the VFD to trip.
- O. A control power transformer shall be sized to handle all the load connected to the control circuits.
- P. The operator panel shall be either discrete push buttons and selector switches or a direct access soft-touch keyboard type with the following functions as a minimum:
  - 1. Run-Stop-Auto-Manual or Hand-Off-Auto
  - 2. Display motor speed, motor amp, and output volts
  - 3. Indicating lights for drive run, drive fault, and power on
  - 4. Ability to read and change the operating function settings, and monitor the operating conditions of the drive.
  - 5. Ability to change function setting while the motor is running.
  - 6. Monitor conditions at faults.

### 2.03 HARMONICS

- A. The VFD shall provide dual built-in DC link reactors to minimize power line harmonics and to provide near utility power factor. VFD's without a DC link reactor shall provide a 5% impedance line side reactor.
- B. The VFD shall be provided with harmonic reduction, as required, to insure that the current distortion limits, as defined in table 10.3 of IEEE 519-1992, are met. PCC<sub>1</sub>, defined as the low voltage side of the distribution transformer, is used for purposes of calculation and referred, by the turns ratio of the transformer, to the PCC defined by the IEEE Recommended Practices as the Consumer-Utility interface. The tables of limits set forth therein are with reference to the PCC (primary side of the main transformer).
- C. Harmonic solutions shall be designed to withstand up to 2% line imbalances with the maximum Current Distortion not to exceed 11% at 100% load.
- D. Harmonic solutions shall be capable of withstanding up to 2% ambient voltage distortion with the maximum Current Distortion not to exceed 12% at 100% load.

### 2.04 INTERFACE FEATURES

- A. VFD shall provide an alphanumeric backlit display keypad which may be remotely mounted using standard 9-pin cable. VFD may be operated with keypad disconnected or removed entirely. Keypad may be disconnected during normal operation without the need to stop the motor or disconnected power to the VFD.
- B. VFD shall display all faults in plain texts; VFD's which can display only fault codes are not acceptable.
- C. The keypad shall feature a 4-line display, and be capable of digitally displaying up to four separate operational parameters or status values simultaneously (including process values with the appropriate engineering unit) in addition to Hand/Off/Auto, Local/Remote, and operating status.
- D. Two lines of display shall allow "free text programming" so that a description, or the actual name, of the equipment being controlled by the VFD can be entered into the display.
- E. Keypad shall provide an integral H-O-A (Hand-Off-Auto) and Local-Remote selection capability, and manual control of speed locally without the need for adding selector switches, potentiometers, or other devices.
- F. VFD keypad shall be capable of storing drive parameter values in non-volatile RAM uploaded to it from the VFD, and shall be capable of downloading stored values to the VFD to facilitate programming of multiple drives in similar applications, or as means of backing up the programmed parameters.
- G. VFD shall indicate which digital inputs are active, and the status of each relay.
- H. VFD display shall indicate the value of any voltage or current signal connected to the analog input terminals.
- I. VFD display shall indicate the value of the current on the analog output terminals.
- J. A red FAULT light, a yellow WARNING light and a green POWER-ON light shall be provided. These indications shall be visible both on the keypad and on the VFD when the keypad is removed.
- K. Dual protection shall be provided to prevent unauthorized changes to the programming of the VFD. The parameters can be locked via a digital input and/or the unit can be programmed not to allow an unauthorized user to change the parameter settings.
- L. A quick setup menu with factory preset typical parameters shall be provided in the VFD to facilitate commissioning. Use of macros shall not be required.
- M. A digital elapsed time meter and kilowatt hour meter shall be provided in the display.
- N. VFD shall provide full galvanic isolation with suitable potential separation from the power sources (control, signal, and power circuitry within the drive) to ensure

compliance with PELV requirements and to protect PLC's and other connected equipment from power surges and spikes.

- O. All inputs and outputs shall be optically isolated. Isolation boards between the VFD and external control devices shall not be required.
- P. There shall be eight fully programmable digital inputs for interfacing with the systems external control and safety interlock circuitry.
- Q. The VFD shall have two voltage analog signal inputs and one current signal input, and shall accept a direct-or-reverse acting signal. Analog reference inputs accepted shall include 0-10 V dc, 0-20 mA and 4-20 mA.
- R. Two programmable analog outputs shall be provided for indication of drive status. These outputs shall be programmable for output speed, voltage, frequency, motor current and output power. The analog output signal shall be 0-20 mA or 4-20 mA.
- S. The VFD shall provide two user programmable relays with 31 selectable functions. One form 'A' 50VAC and form 'C' 230VAC/2A rated dry contact relay outputs shall be provided.
- T. Floating point control interface shall be provided to increase/decrease frequency in response to external switch closures.
- U. The VFD shall accept a NC motor temperature overtemperature switch input, as well as possess the capability to accept a motor thermistor input.
- V. The VFD shall store in memory the last 20 faults and record all operational data.
- W. Run permissive circuits shall be provided to accept a "system ready" signal to ensure that the VFD does not start until isolation valves, seal water pumps or other types of auxiliary equipment are in the proper state for VFD operation. The run permissive circuit shall also be capable of sending an output signal as a start command to actuate external equipment before allowing the VFD to start.
- X. The VFD shall be supplied with a standard RS-485 serial communications data port. A Windows7 compatible software to display all monitoring, fault, alarm, and status signals shall be available. This software shall allow parameter changes, storage of all VFD operating and setup parameters, and remote operation of the VFD.

## 2.05 DESIGN FEATURES

The VFD shall be provided with additional features described below:

- A. Power loss ride-through capability for power loss of 0.2 second.
- B. Additional devices and functions as follows:
  - 1. Drive system disconnect operators.

2. HAND-OFF-AUTO selection.
  3. System speed control selector switches (LOCAL/REMOTE) (When in LOCAL position, speed controlled by a manual speed potentiometer)
  4. Switch for Pump 1, Pump 2 or automatic alternation
  5. Switch for BYPASS/MANUAL mode
  6. Door intrusion alarm system for VFD cabinet
  7. Alarm lights
- C. Drive shall be sized to the KVA requirements of the motor and shall be sized such that the drive does not exceed 90% nameplate rating under any load condition.
- D. Drive shall be provided with built-in PID controller.
- E. The VFD shall be designed to operate from a three-phase 240 or 480 volt, 60 Hz supply and to control a standard 230 or 460 volt three phase 60 Hz squirrel cage induction motor with a 1.15 service factor without derating or requiring any motor modification. The VFD shall vary both the AC voltage and frequency simultaneously to operate the motor at required speeds.
- F. The VFD shall be specifically designed for use with the variable or constant torque load it serves.
- G. The VFD shall be provided with "voltage boost" at low frequency, and adjustable voltage/frequency ratios.
- H. The VFD shall be provided with adjustable minimum speeds between 4 and 40 Hz and maximum speeds between 40 and 80 Hz. Factory minimum and maximum settings shall be 24 and 60 Hz, respectively. Unless otherwise approved by the Department, minimum speed for Variable Frequency Drive pumps shall be set at 60% of maximum speed.
- I. The minimum VFD efficiency shall be at least 95 percent at 100 percent speed, and 85 percent at 50 percent speed.
- J. The VFD shall shut down in an orderly manner when a power outage occurs. Upon restoration of power, the motor shall restart and run at the speed corresponding to the current process input signal.

## 2.06 ADJUSTMENTS

- A. The VFD shall have an adjustable output switching frequency.
- B. Four complete programming parameter setups shall be provided, which can be locally selected through the keypad or remotely selected via digital input(s), allowing the VFD to be programmed for up to four alternate control scenarios without



requiring parameter changes.

- C. In each programming set up, independent acceleration and deceleration ramps shall be provided. Acceleration and deceleration time shall be adjustable over the range from 0 to 360 seconds to base speed.
- D. The VFD shall have four programmable “skip frequencies” with adjustable bandwidths to prevent the driven equipment from running at a mechanically resonant frequency.
- E. VFD shall include an automatic acceleration and deceleration ramp- time function to prevent nuisance tripping and simplify start-up.
- F. In each programming setup, independent current limit settings, programmable between 50% and 110% of the drives output current rating, shall be provided.
- G. An automatic “on delay” function may be selected from 0 to 120 seconds.
- H. The VFD will include a user-selectable Auto-Restart function that enables the VFD to power up in a running condition after a power loss, to prevent the need to manually reset and restart the VFD.

2.07 AIR MOVING EQUIPMENT: All air moving equipment shall be in accordance with Section 15860.

## 2.08 PROTECTION FEATURES

The VFD shall have, as a minimum, the following protection features:

- A. The main circuit breaker shall be mechanically interlocked with the VFD enclosure door. The circuit breaker shall be sized to have a short-circuit interrupting capacity of the motor control centers or switchgear to which the VFD is connected. The breaker shall be provided with provisions for locking open with a padlock.
- B. VFD shall have input surge protection utilizing MOV's, spark gaps, and Zener diodes to withstand surges of 2.3 times line voltage for 1.3 msec.
- C. VFD shall include circuitry to detect phase imbalance and phase loss on the input side of the VFD.
- D. VFD shall auto-derate the output voltage and frequency to the motor if an input phase is lost if it is desirable to maintain operation without decreasing the life expectancy of the VFD. The use of this feature shall be user selectable and export a warning during the event.
- E. VFD shall include current sensors on all three-output phases to detect and report phase loss to the motor. The VFD will identify which of the output phases is low or lost.
- F. VFD shall auto-derate the output voltage and frequency to the motor in the

presence of sustained ambient temperatures higher than the operating range, so as not to trip on an inverter temperature fault. The use of this feature shall be user selectable and a warning will be exported during the event.

- G. The VFD shall have the option of an integral RFI filter. Enclosures shall be made of metal to minimize RFI and provide immunity.
- H. Protection against single phasing, power outage, and reverse phase rotation
- I. Instantaneous overcurrent protection
- J. Electronic overcurrent protection
- K. Ground fault protection
- L. Overtemperature protection and alarm for electronics
- M. Protection against internal faults
- N. Ability to start into rotating motor
- O. Additional protection and control as required by the motor and driven equipment.
- P. The VFD will include a user selectable Reset function, which enables the selection of between zero and twenty restart attempts after any self-clearing fault condition (under-voltage, over-voltage, current limit, inverter overload and motor overload) or the selection of an infinite number of attempts. The time between attempts shall be adjustable from 0 through 600 seconds.

## 2.09 ELAPSED TIME METER

- A. Provide, in addition to the elapsed time meter arrangement described below, a device for measuring and recording pump operation speed.
- B. An elapsed time meter for each pump should record the amount of running time in "hours" and "tenths of hours" that occurs when each pump is running.

## 2.10 FACTORY TESTING

- A. General
  - 1. All components shall be 100 percent tested. All printed circuit boards shall be burned in continuously for 5 hours at 50 degrees C. The printed circuit boards shall be tested after burn-in to insure they are functioning within specification.
  - 2. Control power shall be applied to microprocessors, printed circuit boards, diagnostic boards and similar devices including software to test for proper operation, sequencing, logic and diagnostics.
  - 3. All wiring shall be checked for continuity and for compliance with the wiring

diagrams.

- B. Testing shall proceed in the order given below:
1. Motor test: VFD, along with the actual AC motor to be provided (of VFD manufacturer test motor) shall be tested with the system logic and a dynamometer load to simulate field operation conditions at 25, 50, and 100 percent full load current.
  2. VFD test: After dynamometer tests are complete, the VFD shall be load-tested in a heat room maintained at 40 degrees C for 5 hours. The motor shall be loaded at 100 percent full load current for 1 hour. Motor and dynamometer need not be in the elevated temperature room with the VFD.
  3. Provide above-stated tests in addition to the manufacturer's normal factory tests.
  4. Provide certified documentation of all tests performed.
  5. Failure of any component during this test requires repair and commencement of a new test.

## 2.11 SPARE PARTS

- A. The Contractor shall furnish the spare parts listed below, suitably packaged and labeled with the corresponding equipment number.
- B. During the term of this contract the Contractor shall notify the Design Engineer in writing about any Manufacturer's modification of spare part numbers, interchangeabilities, or model changes. If the Engineer determines that the modified parts no longer apply to the equipment provided, the Contractor shall furnish other applicable parts at no increase in cost to the Owner.
- C. The following spare parts shall be furnished:
1. Two lamp lenses of each color
  2. Two dozen pilot lamps
  3. One of each type of circuit board:
    - a) Control board
    - b) Power board
    - c) Diode board
    - d) Transistor module
    - e) One of each power diode and Transistor

## 2.12 SERVICES OF THE MANUFACTURER

- A. An authorized service representative of the Manufacturer shall be present at the site

to furnish, in entirety, the services listed below.

- B. The authorized service representative shall supervise the following and certify that the equipment and controls have been properly installed, aligned, adjusted, and readied for operation.
  - 1. Inspection, checking, and adjusting the equipment
  - 2. Startup and field testing for proper operation
  - 3. Performing field adjustments to insure that the equipment installation and operation comply with requirements
- C. Manufacturer shall provide all appropriate O&M manuals, interconnect drawings, service information and service representative phone numbers necessary for the continued operation and maintenance of the VFD installation.

### **PART 3 - EXECUTION**

#### 3.01 INSTALLATION AND EXAMINATION

- A. Conduit stub-ups for interconnected cables and remote cables shall be located and terminated in accordance with the drive manufacturer's recommendations.
- B. Contractor to verify that job site conditions for installation meet factory recommended and code-required conditions for VFD installation prior to start-up, including clearance spacing, temperature, contamination, dust, and moisture of the environment. Separate conduit installation of the motor wiring, power wiring, and control wiring, and installation per the manufacturer's recommendations shall be verified.
- C. VFD Cable (3 stranded tinned copper circuit conductors plus (3) symmetrical bare copper ground wires, XLPE insulation, two spiral copper tape shield (100% coverage) ~ sun-and oil-resistant PVC jacket) shall be used in applications other than submersible pumps.
- D. The VFD is to be covered and protected from installation dust and contamination until the environment is cleaned and ready for operation. The VFD shall not be operated while the unit is covered.

#### 3.02 START-UP AND WARRANTY

- A. A factory-authorized service technician shall perform start-up on each drive. ("Start-up" shall not include having the technician perform installation or termination of either power or control wiring.) The service technician shall perform start-up on up to 8 drives per day. The bid item for selling and delivering drives shall include start-up costs, which shall include time and travel for the estimated number of visits required, but shall not be less than at least one half-day with travel. Additional labor

or return trips to the site shall be billed at to the Contractor, at no additional cost to the County. Upon completion, a start-up service report shall be provided.

- B. The drive manufacturer shall provide a 6-year on-site warranty such that the County is not responsible for any warranty costs including travel, labor, parts, or other costs for a full 6 years from the date of manufacture of the Drive. The cost of the warranty shall be included in the bid.

### 3.02 FIELD TESTING

- A. Testing, checkout and startup of the VFD equipment in the field shall be performed under the technical direction of the Manufacturer's service representative. Under no circumstances are any portions of the drive system to be energized without authorization from the Manufacturer's representative.
- B. Harmonic analysis shall be performed at unit full load using a harmonic analyzer by Hewlett Packard, or equal. Tests shall prove that the harmonic distortion is limited to a magnitude of 5 percent of the fundamental with line reactors or isolation transformer in the circuit as indicated. The report shall include the following:
  - 1. Expected harmonic current (THD) through the 9th harmonic, calculated with and without line reactors or isolation transformer.
  - 2. Actual RMS value and measured percentage of the THD in the field.
- C. Provide a copy of the field test data and certify that the unit(s) are installed and tested properly and meet manufacturer's requirements.

**END OF SECTION**